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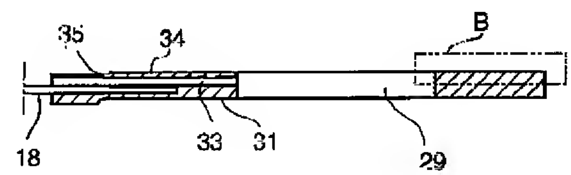
(54) [TITLE OF THE INVENTION] SEPARATOR FOR FUEL-CELL AND MANUFACTURING METHOD THEREOF

(57) [ABSTRACT]
[PROBLEM] To provide a separator for a fuel-cell wherein a flow path having no step is formed within a single frame, and the manufacturing method thereof.
[MEANS FOR RESOLUTION] A separator for a fuel-cell attached to a plastic frame, having a plastic frame having a manifold 29 formed therein, around a separator; being a separator 18 for a fuel-cell wherein is formed a tunnel-shaped flow path 33 that is connected between the manifold 29 and a space on the inside of the inner peripheral surface of a plastic frame in a part of the plastic frame 31 further towards the inner peripheral side than the manifold 29. An inner surface of the separator side part of the flow path 33 is coplanar with the surface of the separator 18. A manufacturing method for a separator for a fuel-cell having a first-stage step for forming a frame intermediate product that is missing a portion that would interfere when a core is removed, and having a tunnel-shaped flow path 33 in a portion that is towards the inner peripheral side from a manifold, wherein a pin-shape core is disposed within a mold for molding the frame intermediate product, and a second-stage step for forming a frame final product wherein the portion that would interfere when removing the core is filled.



[SCOPE OF PATENT CLAIMS]

[CLAIM 1] A fuel-cell separator that is a plastic-framed fuel-cell separator having a manifold formed therein at the periphery of the separator, wherein:

the outer edge portion of the separator is molded integrally with the plastic frame; and

a tunnel-shaped flow path that is connected to the manifold and to a space that is towards the inside of the inner peripheral surface of the plastic frame is molded at a part of the plastic frame that is further towards the inside than the manifold.

[CLAIM 2] A fuel-cell separator as set forth in Claim 1, wherein:

the flow path extends in a straight line through the entire length of the flow path; and

the inner surface of the separator-side part of the flow path is coplanar with the surface of the separator.

[CLAIM 3] A method for manufacturing a fuel-cell separator that is a method for manufacturing a plastic-frame fuel-cell separator having a plastic frame having a manifold built in around the separator, wherein is formed a tunnel-shaped flow path that is connected to the manifold and to a space on the inside of the inner peripheral surface of the plastic frame, at a part that is further towards the inside of the plastic frame than the manifold, comprising:

a first-stage step for forming a frame intermediate product that is missing a portion that would interfere when removing a core, of the portion that is further towards the outer peripheral side than the manifold, having a tunnel-shaped flow path in a portion that is further towards the inside of the plastic frame than the manifold, by placing a pin-shaped core, for forming the flow path, within a mold for molding the frame intermediate product, injecting molten plastic, and, after the plastic has hardened, removing the core; and

a second-stage step for forming a frame final product by placing the frame intermediate product into a frame final product mold, and injecting molten plastic to fill the portion that would interfere when the core is removed and then removing from the mold after the plastic has hardened.

[DETAILED EXPLANATION OF THE INVENTION]

[0001]

[FIELD OF TECHNOLOGY OF THE INVENTION] The present invention relates to a fuel-cell separator having a plastic frame on the outer peripheral portion thereof, and having a tunnel-shaped flow path within the frame.

[0002]

[PRIOR ART] A solid polymer electrolytic fuel-cell is structured from a cell that is structured from a membrane-electrode assembly (MEA) made from an electrode (anode, fuel electrode) that is structured from an electrolytic membrane that is made from an ion-exchanging membrane, and a catalyst layer and diffusing layer that are disposed on one surface of the electrolytic membrane, and an electrode (cathode, air electrode) that is made from a catalyst layer and a diffusing layer that are disposed on the other surface of the electrolytic membrane; and a separator wherein is formed flow paths for supplying fuel gas (hydrogen) and oxidizing gas (oxygen or, normally, air) to the anode and the cathode, or a flow path for carrying a cooling medium; wherein a module is structured from a layered unit of a plurality of cells; wherein modules are layered to form module groups, where, on both layering-direction ends of the module groups are disposed terminals, insulators, and end plates, to form stacks, where the stacks are tightened by a tightening member (for example, a tension plate) that extends, on the outside of the stack, in the direction of layering of the cell layered unit, and then secured. In the individual polymer electrolytic fuel-cell, a reaction takes place on the anode side wherein hydrogen is turned into hydrogen ions and electrons, where the hydrogen ions move through the electrolytic membrane to the cathode side, and a reaction takes place on the cathode side that produces water from oxygen, hydrogen ions, and electrons (where the electrons produced at the anode of the neighboring MEA arrive through passing through the separator).

Anode side: $H_2 \rightarrow 2H^+ + 2e^-$

Cathode side: $2H^+ + 2e^- + (½)O_2 \rightarrow H_2O$

Because heat is produced in the reaction that produces water on the cathode side, flow paths are formed for carrying a cooling medium (which is normally cooling water) in each individual cell or in each plurality of cells (for example, two cells), to cool the fuel cells. Japanese Unexamined Patent Application Publication H8-162131 discloses a fuel-cell separator that has a plastic frame surrounding a metal separator, where fuel gas and oxidizing gas from the respective manifolds that are formed within the plastic frames pass through the flow paths that are formed in the plastic frames to be supplied to the fuel gas flow paths and oxidizing gas flow paths that are formed in the metal separator, to be expelled. Because the MEA layers are held between plastic frames, the groove-like flow paths are exposed to the surface of the plastic frames, where having recessed and raised portions on the sealing surface is undesirable from the perspective of sealing. Because of this, the flow path that are formed in the plastic frame are formed as groove-like flow paths in two frames, and the groove-shaped flow paths are aligned and the two frames are put together to form [the flow paths] within a composite frame made of two frames. The flow paths, en route, bend in the direction of thickness of the frame in order to connect to the flow paths of the reaction gases on one side surface of a separator, and thus a step is formed in the flow path in the bent portion.

[0003]

[PROBLEM SOLVED BY THE PRESENT INVENTION] However, there are the following problems in the conventional fuel-cell separator:

(1) Because flow paths are formed within the composite frame wherein two plates are layered together, there is an additional problem in terms of sealing between the facing surfaces of the two plates. Moreover, this doubles the number of frames, greatly increasing the manufacturing cost, the assembly cost, and the like.

(2) There is a stepped portion wherein the flow path to the reaction gas flow path on the one side surface of the separator from the manifold bends to the direction of thickness of the frame, interfering with the smoothness of the flow of the reaction gas. The object of the invention is to provide a fuel-cell separator, and manufacturing method thereof, wherein a flow path that has no step is formed within the plate thickness of a single frame.

[0004]

[MEANS FOR SOLVING THE PROBLEM] The present invention, which achieves the object set forth above, is as follows:

(1) A fuel-cell separator that is a plastic-framed fuel-cell separator having a manifold formed therein at the periphery of the separator, wherein: the outer edge portion of the separator is molded integrally with the plastic frame; and a tunnel-shaped flow path that is connected to the manifold and to a space that is towards the inside of the inner peripheral surface of the plastic frame is molded at a part of the plastic frame that is further towards the inside than the manifold.

(2) A fuel-cell separator as set forth in (1), wherein: the flow path extends in a straight line through the entire length of the flow path; and the inner surface of the separator-side part of the flow path is coplanar with the surface of the separator.

(3) A method for manufacturing a fuel-cell separator that is a method for manufacturing a plastic-frame fuel-cell separator having a plastic frame having a manifold built in around the separator, wherein is formed a tunnel-shaped flow path that is connected to the manifold and to a space on the inside of the inner peripheral surface of the plastic frame, at a part that is further towards the inside of the plastic frame than the manifold, comprising: a first-stage step for forming a frame intermediate product that is missing a portion that would interfere when removing a core, of the portion that is further towards the outer peripheral side than the manifold, having a tunnel-shaped flow path in a portion that is further towards the inside of the plastic frame than the manifold, by placing a pin-shaped core, for forming the flow path, within a mold for molding the frame intermediate product, injecting molten plastic, and, after the plastic has hardened, removing the core; and

a second-stage step for forming a frame final product by placing the frame intermediate product into a frame final product mold, and injecting molten plastic to fill the portion that would interfere when the core is removed and then removing from the mold after the plastic has hardened.

[0005] The fuel-cell separator as set forth in (1) has a tunnel-shaped flow path formed in a plastic frame, and thus there is no problem with sealing between frames that are laid together as there is in the case of flow paths that are formed by laying together two of the conventional grooved frames, and because what has conventionally been two frames becomes one frame, it is possible to achieve a cost reduction. In the fuel-cell separator as set forth in (2), above, the flow path extends in a straight line through the entire length of the flow path, and the inner wall of the separator-side part of the flow path is coplanar with the surface of the separator, reducing the flow resistance when compared to the conventional flow path that has a bend. In the fuel-cell separator manufacturing method as set forth in (3), above, the frame is fabricated by a two-step process, a step for forming a tunnel-shaped flow path using a pin-shaped core, and a step for filling the portion that is to the outside of the manifold, to enable the easy fabrication of flow paths within a single frame.

[0006]

[FORMS OF EMBODIMENT ACCORDING TO THE PRESENT INVENTION] A fuel-cell separator according to the present invention will be explained below in reference to FIG. 1 through FIG. 6. The fuel-cell according to the present invention is a solid polymer electrolytic fuel-cell 10. The fuel-cell 10 according to the present invention is equipped in, for example, a fuel-cell automobile. However, it may be used in other than automobiles.

[0007] The solid polymer electrolytic fuel-cell 10, as illustrated in FIG. 1 through FIG. 6, is structured through forming cells through stacking membrane-electrode assemblies (MEA), each comprising an electrode 14 (anode, fuel electrode), made from an electrolytic membrane 11, which is made from an ion-exchanging membrane, a catalyst layer 12 that is disposed on one surface of the electrolytic membrane 11, and a diffusion layer 13, and an electrode 17 (cathode, air electrode) that is made from a catalyst layer 15 and a diffusion layer 16 that are disposed on the other surface of the electrolytic membrane 11, and layering separators 18 wherein are formed a flow path 27 for supplying a fuel gas (hydrogen) and an oxidizing gas (oxygen, normally air) to the electrodes 14 and 17 and a cooling water flow path 26 for carrying cooling water for cooling the fuel-cell, structuring a module 19 by layering together a plurality of cells (for example, structuring one module from two cells), layering modules 19 into a module group, structuring a stack 23 by disposing, on both ends of the module group in the direction of layering of the cells (the direction of layering of the fuel cells) terminals 20, insulators 21, and end plates 22, and then tightening the stack 23 in the direction of stacking and securing, using bolts 25 or nuts, and a tightening member 24 (such as a tension plate, a through bolt, or the like) that extends in the direction of stacking of the fuel-cell stack on the outside of the stack 23.

[0008] The catalyst layers 12 and 15 are made from carbon (C) that contains platinum (Pt). The diffusion layers 13 and 16 are made from C. The separator 18 is impermeable, and is normally made from carbon (including when made from graphite), metal, or some sort of electrically conducting plastic. The case wherein the separator 18 is made from a plurality of metal plates is shown below, but the present invention is not limited thereto.

[0009] The separator 18 not only partitions the fuel gas and the oxidizing gas, or the fuel gas and the cooling water, or the oxidizing gas and the cooling water, but also forms electrical paths for carrying electrons to the cathode from the anode of the adjacent cell. Cooling water flow paths 26 are provided for each cell or for each plurality of cells. For example, in a structure wherein a single module is structured from two cells, as illustrated in FIG. 3, a single cooling water flow path 26 is provided for each module (two cells).

[0010] The separator 18 has two types of separators: a cooling separator 18A wherein is formed a cooling water flow path for cooling the fuel-cell and wherein is formed a flow path for the reaction gas, and a reaction gas separator 18B wherein is formed a flow path for a reaction gas. When the separator 18 is made from a metal plate, both the cooling separator 18A and the reaction gas separator 18B are made from metal separators wherein a plurality of metal plates are stacked together. The metal plates are made from, for example, a stainless steel plates that are plated with nickel.

[0011] When the separator 18 is made from metal plates, the cooling separator 18A is made from two metal plates

18a and 18b wherein are formed gas flow paths 27 on the outer surfaces thereof through the formation of recessed and raised portions, and a middle metal plate 18c, held between the two metal plates 18a and 18b, and whereon is formed a cooling water flow path 26 on the back surface side thereof, for a total of three metal plates. The middle metal plate 18c may (or may not) have recessed and raised portions formed therein, and the below illustrates a case wherein the recessed and raised portions have been formed. The recessed and raised portions in the metal plates 18a and 18b may be, for example, dimples (recessed or raised portions wherein the individual recessed or raised portions are not connected to each other), where the recessed and raised portions have cross-sections [sic] that are conically shaped (or, conversely, may be recessed or raised portions that are connected together to form a groove shape), where the recessed or raised portions of the middle metal plate 18c are connected groove-shaped recessed or raised portions. The middle metal plate 18c makes contact with the inner surfaces of the bottom walls of the recessed portions of the metal plates 18a and 18b, to be held by the metal plates 18a and 18b.

[0012] When the separator 18 is made from metal plates, then, in the cooling water separator 18A, the space between the two metal plates 18a and 18b is the cooling water flow path 26. The cooling water flow path 26 is partitioned, by the middle metal plate 18c, into a cooling water flow path 26a on the front side of the middle metal plate 18c, and a cooling water flow path 26b on the back side of the middle metal plate 18c. The width of the recessed portions and the width of the raised portions in the recessed and raised portions of the middle metal plate 18c are equal to each other, so the resistances to the flow in the cooling water flow path 26a on the front side and in the cooling water flow path 26b on the back side are equal, or essentially equal. Additionally, the cooling water enters into the cooling water flow paths 26 on the front and back of the metal plate 18c from a cooling water manifold 28 that is formed in the frame 3 on the outside of the middle metal plate 18c, and, after passing through the cooling water flow paths 26a and 26b, exits into the cooling water manifold 28. In the middle metal plate 18c, an opening 30 is formed for connecting between the cooling water flow path 26a on the front side and the cooling water flow path 26b on the back side, and is formed so as to enable the easy removal of gas. Additionally, in order to prevent electrocorrosion, the metal plates 18a and 18b and the middle metal plate 18c are made from identical materials.

[0013] In the cooling separator 18A, the outer peripheral portions of the metal plates 18a and 18b each extend into the plastic plate-shaped frame 31, and stop before the gas manifold 29 that is formed in the frame 31, and are formed integrated with the frame 31 (for example, may be embedded and insert molded). The outer peripheral portion of the middle metal plate 18c stops at or before the inner peripheral surface of the frame 31, without extending into the frame 31. The middle metal plate 18c contacts the metal plates 18a and 18b, but is not bonded through welding, or the like. When a frame wherein the outer peripheral portion of the metal plate 18a is embedded is separated from a frame wherein the outer peripheral portion of the metal plate 18b is embedded, then the middle metal plate 18c can be removed and replaced. A gasket 32 is disposed between the frame wherein the outer peripheral portion of the metal plate 18a is embedded and a frame wherein the outer peripheral portion of the metal plate 18b is embedded, to seal the cooling water flow path 26 from the outside. Additionally, tunnel-shaped flow paths 33 are formed in the frame 31, where the respective reaction gases (the fuel gas and the oxidizing gas) are supplied from the gas manifold 29 to the respective gas flow paths 27 (the fuel gas flow path 27a and the oxidizing gas flow path 27b), and exhausted therein.

[0014] The reaction gas separator 18B has only the two metal plates 18a and 18b whereon are formed the gas flow paths 27 (the fuel gas flow path 27a and the oxidizing gas flow path 27b) on the outer surfaces thereof, through the formation of recessed and raised portions, and there is no middle metal plate 18c. In the reaction gas separator 18B, no cooling water flows between the two metal plates 18a and 18b. The recessed and raised portions of the metal plates 18a and 18b may be, for example, dimples (recessed or raised portions wherein the individual recessed or raised portions are not connected to each other), where the recessed and raised portions have cross-sections [sic] that are conically shaped (or, conversely, may be recessed or raised portions that are connected together to form a groove shape). In the reaction gas separators 18B, the outer peripheral portions of the two metal plates 18a and 18b are aligned together and embedded in a single frame. The outer peripheral portions of the metal plates 18a and 18b, which have been aligned, stop within the frame 31 before the gas manifold 29. Furthermore, the tunnel-shaped flow path 33 is formed in the frame 31, where the respective reaction gases (the fuel gas and the oxidizing gas) are supplied from the gas manifold 29 to the respective gas flow paths 27 (the fuel gas flow path 27a and the oxidizing gas flow path 27b), and exhausted therein.

[0015] The membrane-electrode assembly (MEA), in the cooling separator 18A, is held by the raised portions of the recessed and raised portions of the metal plate 18a (or 18b), and the raised portions of the recessed and raised portions of the metal plates 18a (and 18b) of the reaction gas separator 18B, where the electrode portion is cooled directly by the cooling water on the back side. The outer peripheral portion of the membrane-electrode assembly (MEA) is held between adjacent frames 31, where the membrane 11 extends further towards the outer periphery than the electrodes 14 and 17, to be held between the adjacent frames 31.

[0016] FIG. 5 and FIG. 6 illustrate a magnified structure for the plastic frame 31, the separator 18, and the tunnel-like flow path 33 in a plastic-framed fuel-cell separator 18 that has, surrounding the separator 18, a plastic frame 31 that has a manifold 29 on the inside thereof. The outer edge portions of the metal plates 18a and 18b of the separator 18 (which are graphite plates in the case that the separator 18 is made from graphite) are formed integrally (through, for example, embedding an insert molding) at the time of forming the frame 31, at a part on the inner peripheral side of the gas manifold 29 of the plastic frame 31, which is made from a flat frame that is essentially square, with the portion that is essentially in the center removed. The metal plates 18a and 18b may be formed with a single metal plate

insert molded in the frame 31, as is the case for the cooling separator 18A, or, as in the case of the reaction gas separator 18B, may be formed with the two metal plates 18a and 18b laid together and insert molded into the single frame 31.

[0017] A tunnel-shaped flow path 33 that connects the manifold 29 to the space wherein the reaction gas (the fuel gas or the oxidizing gas) flows on the inside of the inner peripheral surface of the plastic frame is formed in the portion of the plastic frame 31 that is further towards the inner peripheral side from the gas manifold 29. The flow path 33 is formed using a core (a pin-shaped core) at the time of molding the plastic frame 31, and thus is formed within the range of the thickness of the single frame 31. Consequently, the flow path is not made from grooves in frames wherein two plates are put together, as is the conventional case. The flow path 33 extends in a straight line through the entire length of the flow path, and has no bend in the direction of thickness of the frame, as in the conventional case. Because the flow path 33 extends in a straight line, the pin-shaped core can be removed in the direction of the axis of the core at the time of molding. The inner surface of the portion of the flow path 33 on the separator 18 side is coplanar with the surface of the separator 18. Consequently, there is no interference between the separator 18 and the core at the time of molding.

[0018] The plastic-framed fuel-cell separator, described above, having a plastic frame 31 with a manifold 29 included therein at the periphery of the separator 18, and formed with a tunnel-shaped flow path 33 that connects from the manifold 29 to the space towards the inside of the inner peripheral surface of the plastic frame, formed in a part of the plastic frame 31 that is towards the inner periphery side from the manifold 29, is manufactured through the following first-stage step, described below, and second-stage step that is performed thereafter. In the first-stage step, a pin-shaped core for fabricating the tunnel-shaped flow path is disposed within a mold for molding a frame intermediate product, molten plastic is injected, [the frame intermediate product] is removed after the plastic has hardened, and the core is removed, to form a frame intermediate product having a tunnel-shaped flow path 33 in a portion of the plastic frame 31 that is towards the inner peripheral side from the manifold 29, wherein the part that is towards the outer peripheral side from the manifold 29 that would interfere with the core at the time of the removal of the core (the portion within the double dotted line B in FIG. 5) is missing. In the second-stage step, the frame intermediate product that was manufactured in the first-stage step is disposed within a mold for molding the frame final product, and molten plastic is injected to fill the portion that was missing in order to [avoid] interferences when removing the core (the portion within the double dotted line B in FIG. 5), and removed from the mold after the plastic hardens, to fabricate the frame final product. In this way, the frame part is fabricated in two stages.

[0019] While the description above was primarily for the case wherein the separator 18 is a metal separator, the separator 18 is not limited to a metal separator, but need only be a separator that is impermeable to gases and liquids and that has electrical conductivity, and may be, for example, a graphite separator or an electrically conductive plastic separator. Additionally, although the flow path 33 was explained for the case of a flow path that connects between the gas manifold 29 and a reaction gas flow path, there is no limitation thereto, but rather the flow path may be for connecting between a cooling water manifold 28 and a cooling water flow path 26 within the separator.

[0020] The operation of the fuel-cell separator as set forth in the present invention will be explained next. Because the tunnel-shaped flow path 33 is formed in the plastic frame 31, there is no problem with sealing between the frames that are laid together, as there is in the case of the flow path that is formed by laying together the conventional grooved frames. Additionally, while conventionally the frames were composite frames made by laying together two frames, in the present invention there is a single integrated frame 31, thus making it possible to achieve a cost reduction through simplifying the manufacturing and reducing part counts. Furthermore, the flow path 33 extends in a straight line through the entire length of the flow path, and the inner surface of the flow path 33 on the part that is on the separator 18 side is coplanar with the surface of the separator 18, reducing the resistance to flow when compared to the conventional flow path. In addition, the flow path 33 is formed within the scope of thickness of the frame 31, in a structure wherein the flow path 33 is not exposed to the stacking surface 34 of the frame 31, and thus the sealing surface for the electrolytic membrane 11 of the MEA is flat, enabling sealing through the membrane 11 being held between the flat sealing surfaces of adjacent frames 31. If the recessed and raised portions for the flow path were to be exposed in the form of grooves on the sealing surface, then the membrane would fall into the grooves, and the sealing would be incomplete; however, such is not the case. Note that in FIG. 5 there is a step 35 at the inner peripheral portion of the stacking surface 34 of the frame 31, but this is a step for absorbing the step between the diffusion layer and the membrane 11 in the MEA, and the electrolytic membrane 11 extends to the outside from this step 35, and so the sealing is between the flat sealing surfaces of adjacent frames 31.

[0021] In the method for manufacturing the fuel-cell separator 18 as set forth in the present invention, the frame 31 is fabricated through a step for fabricating the flow path 33 using a pin-shaped core, and a step for filling the portion that is outside of the manifold 29, in a two-step process, and thus the flow path 33 can be formed easily within a single frame 31.

[0022]

[Effects of the Invention] The fuel-cell separator as set forth in Claim 1 forms a tunnel-shaped flow path in a plastic frame, and thus there is no problem with sealing between frames that are laid together, as there is for a flow path that is formed through laying together two conventional grooved frames, and the frame, which has been conventionally two frames, being only a single frame, enables cost reductions. In the fuel-cell separator as set forth in Claim 2, the tunnel-shaped flow path extends in a straight line through the entire length of the flow path, and the inner surface of the part of the flow path on the separator side is coplanar with the surface of the separator, and thus the resistance to flow is reduced relative to the

conventional flow path wherein there was a bend. In the method for manufacturing the fuel-cell separator as set forth in Claim 3, the frame is fabricated using a two-stage process, comprising a step for forming the tunnel-shaped flow path using a pin-shaped core, and a step for filling the part that is outside of the manifold, thus enabling the fabrication of the flow path easily within a single frame.

[BRIEF DESCRIPTION OF THE DRAWINGS]

FIG. 1 is an overall schematic diagram of a fuel-cell provided with a separator as set forth in an example of embodiment according to the present invention.

FIG. 2 is a cross-sectional diagram of the end portion of a fuel-cell module, and the vicinity thereof, in an example of embodiment according to the present invention.

FIG. 3 is an expanded cross-sectional diagram of a portion of an electrolytic membrane-electrode assembly in a fuel-cell as set forth in an example of embodiment according to the present invention.

FIG. 4 is a plan view of a middle metal plate of a cooling separator in an example of embodiment according to the present invention.

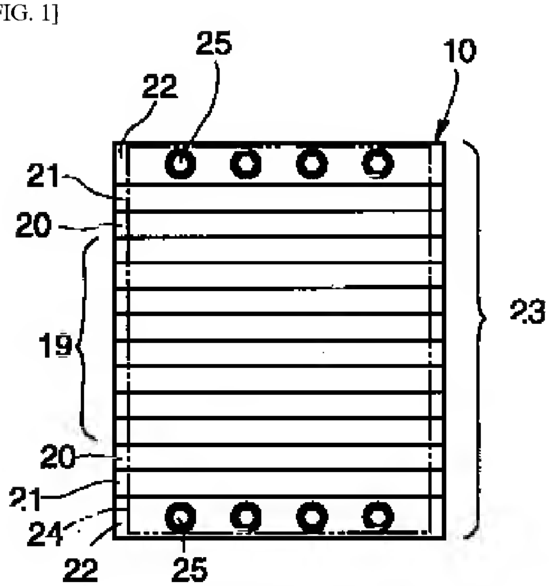
FIG. 5 is a cross-sectional diagram (along the section A-A in FIG. 6) of the parts of a separator and a plastic frame in the vicinity of the tunnel-shaped flow path in an example of embodiment according to the present invention.

FIG. 6 is a plan view diagram of the part of the separator and the plastic frame in the vicinity of the tunnel-shaped flow path in an example of embodiment according to the present invention.

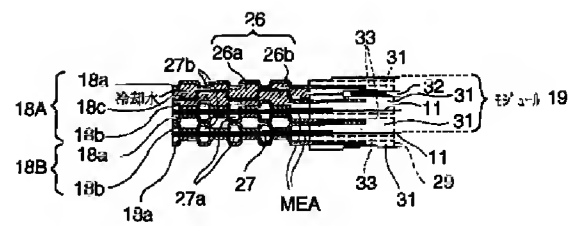
[EXPLANATION OF CODES]

10: (Solid Polymer Electrolytic) Fuel Cell
11: Electrolytic Membrane
12: Catalyst Layer
13: Diffusion Layer
14: Electrode (Anode, Fuel Electrode)
15: Catalyst Layer
16: Diffusion Layer
17: Electrode (Cathode, Air Electrode)
18: Separator
18A: Cooling Separator
18B: Reaction Gas Separator
18a, 18b: Metal Plates
18c: Middle Metal Plate
19: Module
20: Terminal
21: Insulator
22: End Plate
23: Stack
24: Tightening Member (Tension Plate)
25: Bolt or Nut
26: Cooling Water Flow Path
26a: Middle Metal Plate Front Surface-Side Cooling Water Flow Path
26b: Middle Metal Plate Back Surface-Side Cooling Water Flow Path
27: Gas Flow Path
27a: Fuel Gas Flow Path
27b: Oxidizing Gas Flow Path
28: Cooling Water Manifold
29: Gas Manifold
30: Opening
31: Frame
32: Gasket
33: (Tunnel-Shaped) Flow Path
34: Stacking Surface
35: Step

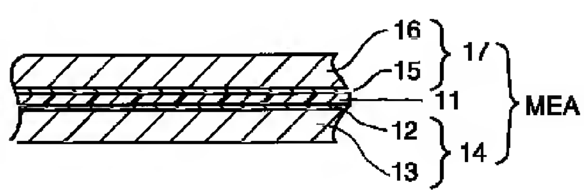
[FIG. 1]



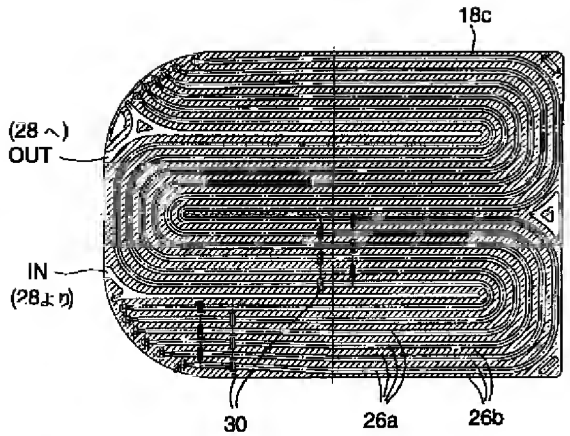
[FIG. 2]



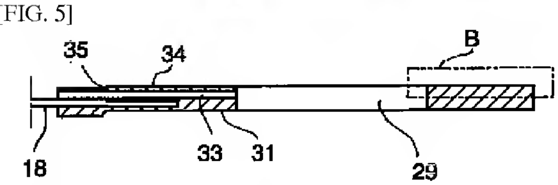
[FIG. 3]



[FIG. 4]



[FIG. 5]



[FIG. 6]